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By

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Following the suggestion of pilot study in which dual performance of shadowing and simple RT tasks was demanded of *S*s with the result that RT became worse, the stage of interference was investigated using between-subject design. There were five conditions in all: They were I condition in which *S*s were required to repeat verbal material after it was over while doing RT task during listening, O condition in which *S*s similarly repeated the same material in addition to RT task this time performed during repetition, S condition in which *S*s performed shadowing and RT task simultaneously, and two control conditions in which *S*s did not have to attend to sentences but were required merely to do *RT* task at the comparable moment to the I and O conditions respectively. It was found that I condition RT was comparable to the Cont. -I condition RT, while O condition RT was nearer to that of S condition. Thus, it seemed that slowing of RT when combined with shadowing would have been brought about by the response side factor. However, two problems were pointed out: one was the effect of screening of the subjects upon the sampling bias, and the other was that of memory load upon RT of O condition. Further experiments concerning memory load effect was also reported.

Recently information processing approach has become one of the most exciting areas in psychology. In this field, problems concerning attention or stimulus selection have been one of the most fascinating and controversial ones that have attracted many researchers all over the world. Of various techniques used to attack the problems one of the most popular experimental paradigm would be that of dichotic listening. It has been amply demonstrated with this method that one cannot attend to two sources of information at once (Moray, 1969). This sort of results led Broadbent (1958) to propose a now classical model of human information processing which he assumed to possess only one channel of limited capacity. However, dichotic listening experiment is not a sensitive technique to assess the extent to which information presented to the unattended channel is processed, for it relies heavily on memory in the assessment. As it is usually designated as primary task for the subject to "shadow" or monitor the material presented to the attended channel, it is highly likely that he cannot respond to the material presented to the unattended channel as quickly as possible as he must first switch his attention to the unattended channel and this switching would consume some time for the system with minimal dwell time of about 250 msec (Moray, 1969). Then the obtained results would be ambiguous in that they reflect not only the effect of attention but also that of delay or memory which is obviously not the same thing as attention. For example, Norman (1969) has shown that if probed

immediately subjects could report the content of the unattended channel, but if a probe was delayed 20 sec or so they could no more report it. Although Norman's experiment dealt with different order of delay, it illustrated the point that delay in assessment should be removed, if one wishes to assess the capacity of the unattended channel without being confounded with a memory factor. Thus, what is required is a real time indicator of performance such as reaction time rather than detection measure such as d'.

Besides, dichotic listening type of experiments presents two materials which are usually both verbal. Condidering the recent research (Gazzaniga, 1970) on the bisected brain which showed that man is equipped with two separate processors which are normally connected by corpus callosum, but differ in the kind of materials to process, it does not seem to be the best way to present two materials similar in kind such as verbal ones.

With these points in mind, a pilot study was conducted in which shadowing of prose was coupled with visual RT task. These two tasks were chosen with the consideration that reaction time would reflect in real time the degree to which the system could operate as a parallel processor. Recent studies (Allport *et al.*, 1972; Shaffer, 1975) suggest such a possibility, although other interpretation of the results would be possible. For example, Kahneman's (1973) capacity allocation model or Norman and Bobrow's (1975) resource model of attention would explain the obtained results as due to the fact that skilled performances such as typewriting and playing the piano by sight-reading were well-practiced and thus became "automatic" in performance (Kimble and Perlmuter, 1970). Therefore, performance of these tasks left much spare capacity for the other task to be performed normally at least in appearance.

The results of the pilot study indicated that RT to a visual stimulus became slower by about 100 msec if combined with shadowing, suggesting some interference somewhere in the information processing stages. Observation of *S*s' behavior and their self-reports, however, seemed to suggest that the stage of interference resided in response execution side rather than stimulus encoding side. For example, some of the *S*s reported that they tended to forget the content of prose to be shadowed the moment stimulus light came on. In this respect the results of the experiments concerning psychological refractory period is suggestive in that they indicated that the effect was brought about by some interference in the response execution side (Herman and Kantowitz, 1970; Kantowitz, 1974; Keele, 1973; Reynolds, 1964). However, as *S*s had to do both listening to the tape and repeating it in shadowing, it is uncertain which of these two performances were the cause of interference. Thus, the present study was planned to investigate specifically whether interference effect of shadowing was derived from listening or verbal response by separating these processes and comparing their effect upon RTs with that of shadowing.

Method

Subjects: 50 undergraduates and graduates served as subjects, some of whom majored in psychology. All the subjects were acquaintances of the experimenter or acquaintances of his acquaintances and asked to volunteer as subjects. No reward was given to them.

Apparatus: Subjects were tested one by one with a TKK Multi Unit System, which presented a visual signal and registered *S*s' reaction times to it. A red light emitting diode (LED) was used as a stimulus source. It was directly driven by the output of the Multi Unit System. Verbal materials were recorded on a cassette tape and presented to *S* through headphone. *S*'s verbal responses to the messages were recorded by another tape recorder.

Material: 60 sentences were prepared, which consisted of 6 segments (*Bunsetsu*). They were chosen from a selection of folk tales and trimmed to become 6 segments. The duration of the stimuli was about 4 to 5 seconds. The interstimulus interval was 10 seconds. These materials were tape-recorded by female voice.

Design: A between-subject comparison design was used. Thus, each of the subjects was assigned randomly to one of 5 groups, that is, Input (I) condition, Control-Input (Cont. -I) condition, Otuput (O) condition, Control-Output (Cont. -O) condition, and Shadowing (S) condition. Each group consisted of 10 subjects (7 males and 3 females). The I group were asked to listen to the tape and repeat the sentence just after it was over while watching LED embedded in a black screen facing to them in order to respond to it as quickly as possible, and were told that LED would come on when they were listening to the tape. Cont. -I group were instructed in the same way as I condition except that they were told that they did not have to repeat the tape. O group were told that they should repeat the sentences and respond to LED as quickly as possible as the stimulus would come on while they were repeating the tape. The instruction to Cont. -O group was the same as that to O group except for the unnecessity of verbal repetition. S group were asked to repeat the sentences as soon as they started, thus shadowing them and to respond to LED while doing so.

Procedure: On being introduced to the experimental room each subject received a card on which instruction was typed according to the condition assigned to him. After the confirmation of his understanding of the instruction, *S* underwent 10 simple reaction time trials as a practice, then went through 60 trials in which they both heard the verbal materials and responded to LED. On first 20 trials LED came on every time in order to make *S*s accustomed to the experimental situation. These trials were run for practice and discarded from analysis. On the residual 40 trials LED were on randomly half of every 10 trials. In addition to the initial 20 trials, further 10 trials on which LED was on randomly 5 times were also recarded as practice. When *S*s made mistakes in verbal responses, the RT's if they occurred concurrently, were not included in the data.

LED was manually put on by the experimenter about 2.5 sec after the beginning

or end of the sentences. This was done by his pushing a button synchronously with the beginning or end of the sentences, thus starting a delay circuit which then drove the timer unit and LED. It was put on for 50 msec.

Results

As some of the *S*s of I and O conditions made too many errors in verbal task, they were considered to be inappropriate and discarded from the pool of experimental subjects. This measure was taken with the following considerations: In order to compare the RT data of these groups with those of S group, experimental conditions should be otherwise as similar as possible among S, O, and I conditions. However, as the *S*s of I and O conditions were delayed to repeat the sentences until the end, they were forced to retain them till the time of repetition. Consequently, there was the possibility that their RTs were contaminated with the effect of retention. In particular, those *S*s who found it hard to retain the material would have devoted more resources to retrieval, thus leaving less residual capacity for RT task. Consequently, memory load effect could be minimized by eliminating these subjects from the population. In this connection, Norman (1968) suggested that retrieval from immediate memory is automatic and effortless whereas that from longer-term memory required much mental operation. As for the I condition *S*s, it was of utmost importance that they should have remembered the sentences, as this was the only evidence that they had attended to the verbal task. Thus, in either case, it seemed possible that the RTs of those *S*s who showed relatively poor performance in memory would not really reflect the effect of concurrent performance. Actually, those *S*s who made more than 8 errors out of the 40 experimental trials were screened out. The number of the *S*s thus eliminated amounted to 16 (6 for O condition, 10 for I condition).

Median RTs were obtained for each subject and averaged over the *S*s for each condition. The results are shown in Fig. 1. Since S condition can be regarded as covering both input and output sides, S condition's averaged RTs were grouped together with those of I and Cont. -I conditions on one hand, and with those of O and Cont. -O conditions on the other. One way analyses of variance were conducted separately on these two sets of RTs, which revealed significant differences both among the three input side conditions ($p<.05$; $F=3.58$, $df=2,27$), and among output side conditions ($p<.005$; $F=9.57$, $df=2,27$). In addition, multiple comparisons within each of the two sets of RTs were made using the Newman-Keuls method with the result that only S and Cont. -I differed significantly for the input side, while both S and Cont. -O and O and Cont. -O differed reliably for output side comparisons.

Furthermore, in order to clarify the effect of key pressings on verbal task, within-subject comparisons of verbal errors between the trials on which no key pressings were required and those on which key pressings occurred were made for I and O conditions respectively. (S conditions *S*s made few errors in repetition.) It was found that 9 out of 16 *S*s (For these comparisons, the *S*s not included in RT data analysis were also

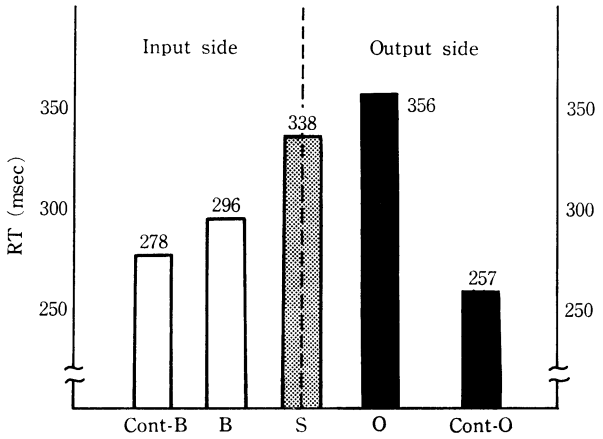

Fig. 1. RTs for each conditions as grouped according to input or output. (Figures attached to the right shoulders of the bars show average RTs).

included to know the general trend of the mutual interferences of dual performance.) made more errors when they did two tasks simultaneously for I condition, whereas only 4 out of 14 *S*s did so for O condition. Sign tests revealed no significant differences for both the comparisons. As for the O condition, however, the tendency was rather contradictory to the common sense expectation that doing two things simultaneously would deteriorate both the tasks involved. On the other hand, comparisons of the errors of the 10 *S*s who made 8 or less than 8 verbal errors showed that 6 out of 7 *S*s made more errors on the dual-task trials ($p=.062$) for I condition, while only one of the 7 *S*s did so for O condition. Thus, for I condition *S*s tended to make more errors during dual-task performance. The O condition's result was similar to that of the whole subjects.

In order to check the biasing effect of subject screening upon RT data, intercorrelations between median RTs and number of errors were calculated for I and O conditions. Product moment correlation coefficient for I condition was found to be .682 ($N=18$, $p<.01$), whereas that for O condition was .096 ($N=18$, n. s.). Thus, these results seem to imply that while it had no effect upon RT to eliminate those subjects who were judged to be unsuitable for the experiment for O condition, it decreased RT by selectively sifting out slow responders for I condition.

Discussion

RT data showed that the slowing of RT when coupled with shadowing task would be more comparable to the slowing by being coupled with verbal repetition than to that caused by listening. In other words, response competition or response conflict would be a major factor of the dual task interference effect as reflected in RT data. As mentioned above, several investigators suggested such a possibility as to psychological

refractory period experiments. Besides, there are several studies which pointed to the same direction, namely, processing neck resides in the response execution side rather than in the stimulus encoding side (Fisher, 1975; Miller, 1975; Posner and Boies, 1971). However, this conclusion must be counterpoised by the fact that the screening procedure seemed to affect the I condition RT data by selectively eliminating those *S*s who tended to show increased RTs when dual-task performance was required.

Apart from the interpretation of RT data, positive correlation between RT and number of errors found for I condition is of itself interesting, as it seems to imply that stimulus encoding is not performed by a single channel system. If it were so, negative correlation would be obtained, since single channel system would deal with input channels one by one, thus information presented to a favored channel would be processed first at the expense of the one presented to the unfavored channel. Another interpretation of the positive correlation is, however, possible that this is an indication of overload disruption of the system. A system that is overloaded by too many tasks imposed simultaneously would show deterioration in performance below normal level of operation owing to switching time among channels or to too little resources allocated to each channel. Specifically, those *S*s for whom dual task performance was too much to cope with might have suffered more severely than those for whom it was within their capacity. Perhaps, instruction should have been stated differently if at least one of the dual tasks had been performed normally. In the present experiment simultaneous performance of the two tasks was demanded rather than giving priority to one of the tasks. This was because the purpose of the experiment was to study whether or not it is possible for one to show parallel processing under some circumstances.

As was pointed earlier, there is the possibility that the RT data of O condition might be contaminated with the memory load effect. This point was specifically investigated in further experiments (Iwasaki, 1976), which showed that such may be really the case. These experiments adopted similar conditions to O condition except for LED being on about 0.5 sec after the initiation of verbal response. The *S*s were

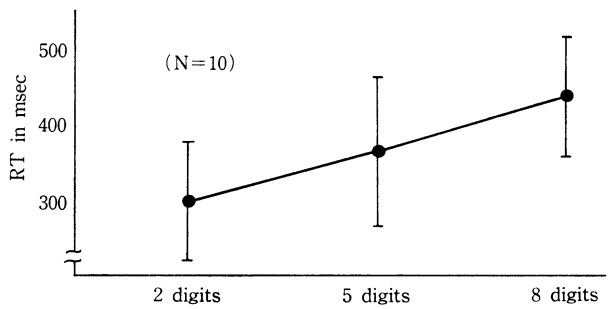

Fig. 2. Mean RTs as a Function of Memory Loads

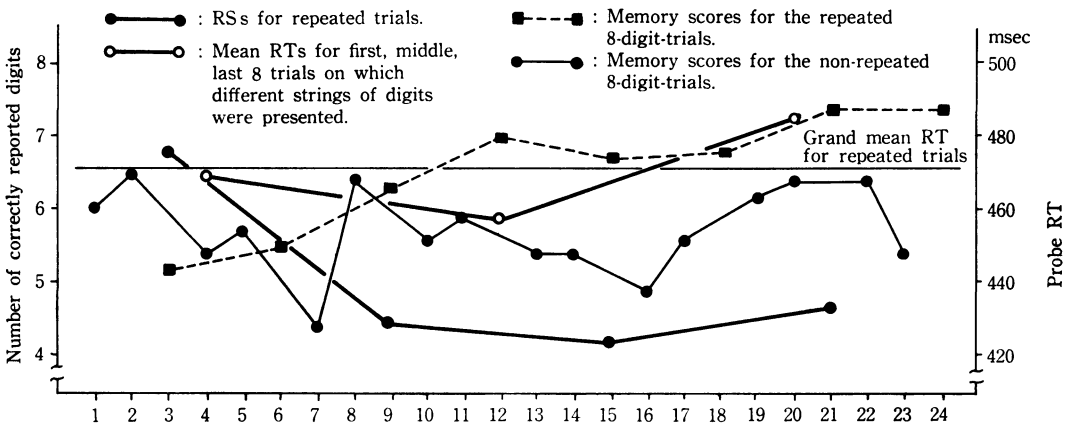

Fig. 3. Mean RTs and memory scores. In this experiment, 19 *Ss* paticipated in the experiment. Each *S* underwent one series of 24 trials. The same string of 8 digits was presented repeatedly on every third trials. RTs were measured concurrently for the 3rd., 9th., 15th., and 21st. trials on which the same string of digits was repeatedly appeared. The other RTs were randomly distributed over the whole trials.

required to remember 2, 5, and 8 random digits. RTs showed linear increase as the number of digits to be retained increased (see Fig. 2). Furthermore, as retention of 8 digits was made easier by presenting them repeatedly every third trials, their reaction times decreased correspondingly, although this decremental trend was not statistically significant (see Fig. 3 for overall summary of the results). Thus, it seems evident that concurrently measured RT really reflects memory load or more precisely retrieval load. This is in line with the results obtained by Trumbo and Milone (1971), who showed that processing load of item retrieval could be indexed by concurrently performed manual tracking task. Although the degree to which O condition RT was influenced by memory load factor cannot be inferred from these results, if the difference between 2-digit RT and 5-digit RT is used as a rough estimate of memory load factor which would have inflated the RT for O condition, then O's RT approaches Cont. -O. In this case, however, it follows that shadowing was a special task that could overload human information processor, which seems to be a rather unlikely conclusion.

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